Final Report to Virginia Coastal Zone Management Program

INSTAR Refinement for Reach Level Analysis
NOAA Task 93.04

Submitted by:

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INteractive **ST**ream **A**ssessment **R**esource (INSTAR)

Background

A key role of Virginia's natural resources agencies is the identification, restoration, and protection of streams, rivers, and riparian corridors that contribute important ecosystem services or represent significant ecological resources. Challenges associated with these important efforts include: 1) development and application of objective, quantitative, and diagnostic stream assessment protocols and 2) defining a set of measurable and appropriate stream conditions, based on empirical data, as goals for restoration and protection efforts. Both of these challenges are dependent on an understanding of, and comparison to, relevant reference conditions that describe accurately and quantitatively the ecological potential of streams and rivers within a specific region. In Virginia, the lack of relatively undisturbed streams to serve as reference systems is especially problematic in the Coastal Zone, Piedmont, northern Virginia, and the Shenandoah Valley, and compromises stream assessment and protection activities for these regions.

Recent studies in Virginia and elsewhere also suggest that results from standard stream assessment protocols (e.g. Rapid Bioassessment Protocols *versus* Indices of Biotic Integrity *versus* geomorphologic stream classification) often present conflicting views of stream health or status, even when the data on which assessments are based are temporally and spatially synoptic. The lack of agreement among standard stream assessment methods is problematic and may limit the appropriate application of these widely-used protocols, even where valid, regional reference conditions are available. Furthermore, current approaches to stream assessment may not support useful comparisons of conditions across broad spatial (i.e., geographic) scales or among major watersheds.

A New Approach to Stream Assessment

In response to the problems outlined above, Virginia Commonwealth University, the Virginia Department of Conservation and Recreation, and the Coastal Management Program of DEQ initiated a multi-phase project to develop an integrative, objective, and statistically valid stream health assessment application. The project uses high quality archival data, combined with extensive, new data collected by the VCU stream assessment team, to develop a broad suite of georeferenced databases of aquatic resources, including fish and macroinvertebrate communities, instream and riparian habitat, and geomorphological data. These databases are the foundation for the ***IN***teractive ***ST***ream ***A***ssessment ***R***esource (***INSTAR***) application: an online, interactive mapping and database application designed to quantitatively assess stream conditions based on comparisons among a suite of integrative, multimetric indices and 'virtual' reference stream models.

INSTAR, and the extensive aquatic resource database on which it runs, were developed to support a variety of stream assessment, management and planning activities aimed at

restoring and protecting water quality and aquatic living resources throughout the Commonwealth. The project is currently focused on developing an aquatic resources (blue infrastructure) database and stream health assessment protocols for Virginia's portion of the Chesapeake Bay watershed. In addition, regional reference stream models (i.e., *virtual* streams) for both non-tidal and small to medium-sized tidal tributaries will be developed as criteria for prioritization of candidate streams and watersheds for protection and restoration, objective and quantitative performance measures, and as a decision support tool for environmental planning and implementation. The *INSTAR* program (http://instar.vcu.edu) and related applications developed by VCU leverage cutting-edge, information technologies (e.g. MS SQL, ArcIMS, ArcGIS Server) and an expanding database of high-quality, geospatial information to conduct both statewide (hydrologic unit scale) and site/reach specific assessments of stream and river health throughout the Commonwealth. Currently, *INSTAR* has compiled information on approximately 1,300 Virginia streams and *INSTAR* databases comprise over 150,000 records, including a substantial amount of new data for the Coastal Zone.

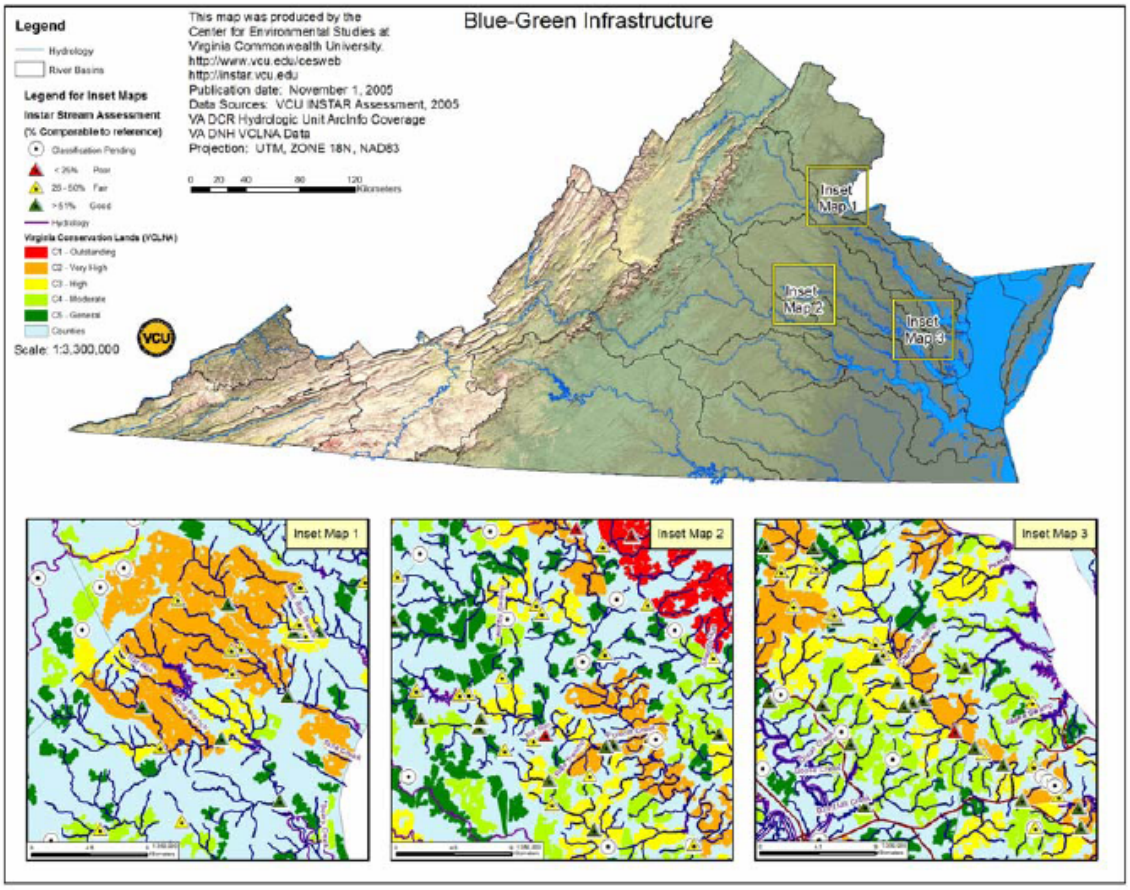
Methods

Probabilistic study reaches for *INSTAR* sampling are selected through a statistically powerful, stratified (by stream order) random design. Within each geo-referenced reach (150-200 m), fishes are sampled quantitatively using electrofishing equipment (backpacks, tote barge units, boats) and standard methods. Backpack and tote barge sampling is performed throughout the entire reach in a single pass. Boat electrofishing may include additional sampling effort depending on stream width and habitat variability. All fishes are identified to species in the field, checked for anomalies, and released. Macroinvertebrates are collected using modified EPA Rapid Bioassessment Protocols (RBP III) for multiple habitat collections using D-frame dipnets. Each major stream habitat type is sampled separately in proportion to its presence in a stream; those samples are composited into one sample representing the stream reach, and macroinvertebrates are then enumerated and identified in the lab to the lowest practical taxon, generally at the genus level.

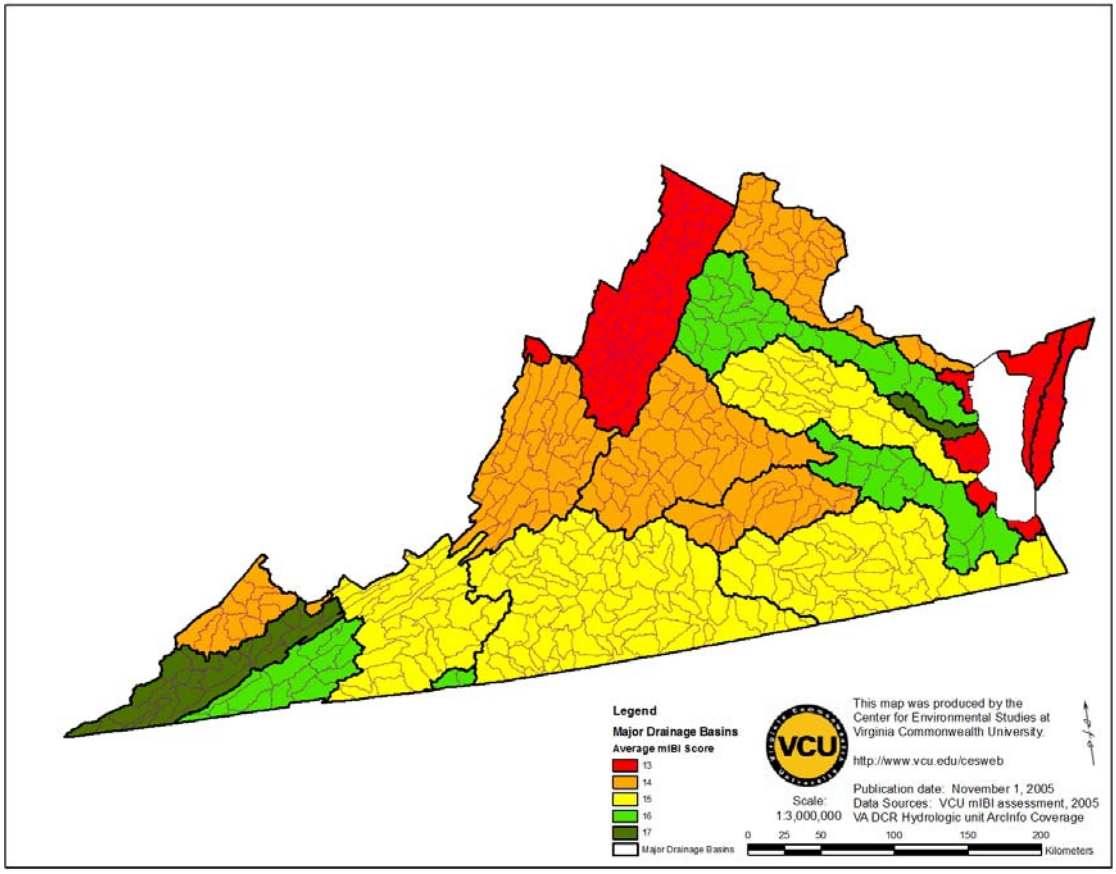
Data are compiled in Access® databases and application macros within INSTAR calculate over 50 separate metrics and ecological variables, including those typically generated for the Index of Biotic Integrity (IBI), Rapid Bioassessment Protocol (RBP), Rapid Habitat Assessment (RHA), and Rosgen-type stream morphology classification. Variables and metrics are then subjected to ordination and cluster analysis using unimodal models (e.g. correspondence analysis (CA), detrended correspondence analysis (DCA), and canonical correspondence analysis (CCA)) and linear response models (e.g. principal components analysis (PCA), multiple regression techniques). The site scores (i.e., coefficients from the final response model) are entered as the response variable and significant ($P<0.05$) biotic and abiotic variables and metrics are entered as explanatory variables, and used to develop a series of reference stream models (i.e., *virtual* streams). We used Gower's similarity index to compare empirical scores obtained from sampled stream reaches to the appropriate virtual reference stream, generating an index of stream health as a measure of percent comparability to the appropriate (*virtual*) reference

condition model. High percent comparability scores (> 75%) are assumed to represent streams with high ecological integrity. Current reference stream models for upper and lower Coastal Plain streams include variables representing fish and macroinvertebrate assemblage structure, instream habitat, and geomorphology, and have substantial explanatory power (R^2 up to 0.74). This integrative approach eliminates many of the limitations typically associated with traditional bioassessment methods (e.g. RBP, IBI), including lack of appropriate reference sites and stream classifications that are based on a single ecological component (e.g. biotic *versus* abiotic, fishes *versus* macroinvertebrates) that may not be diagnostic under many conditions.

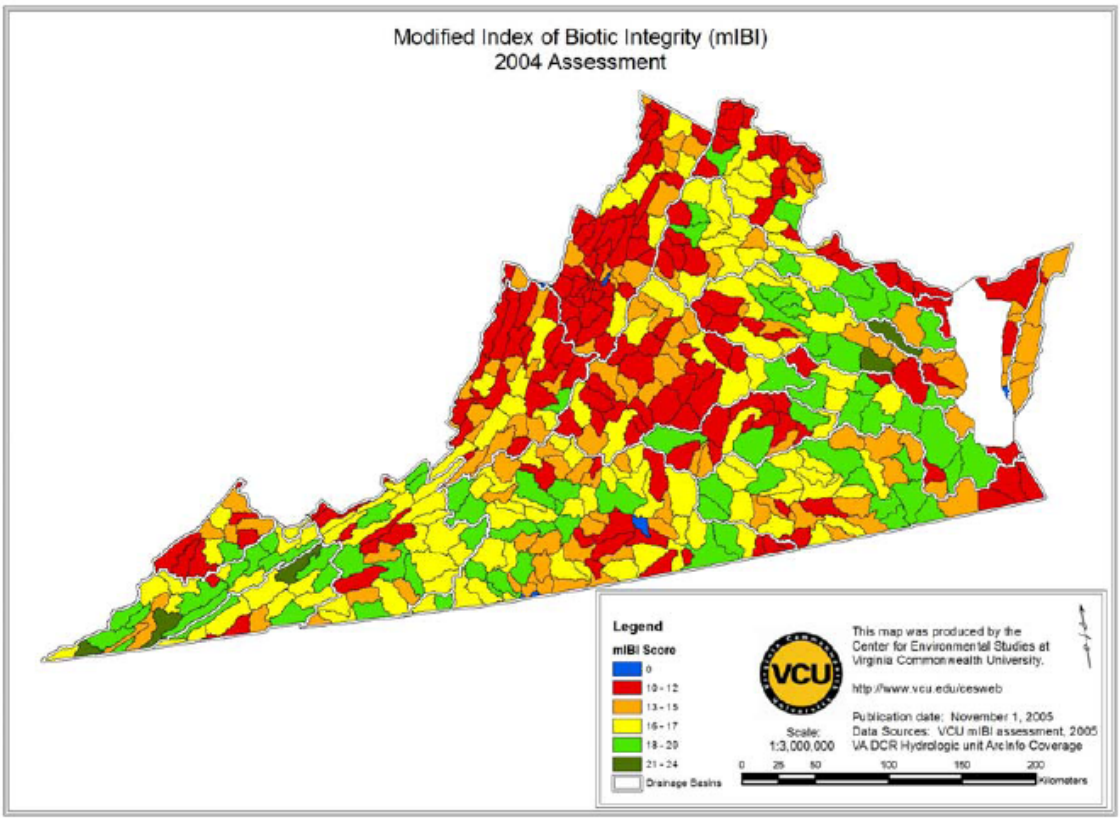
Selected 'universal' metrics (e.g. combined native species richness, percent of pollution-tolerant species, combined non-indigenous species richness) are also used by *INSTAR* to generate a modified Index of Biotic Integrity (mIBI) that classifies each of Virginia's 494, 14-digit watersheds (hydrologic units, HUCs) as a function of stream health, using both quantitative and qualitative (species occurrences) records available for the watershed. Using these two novel approaches, INSTAR is able to support integrated stream health and watershed condition assessments at broad (statewide mIBI classification of HUCs) and fine (percent comparability to virtual reference stream models) geospatial scales. Appropriate quality assurance and control (QC/QA) procedures are followed for all *INSTAR* field and laboratory protocols.



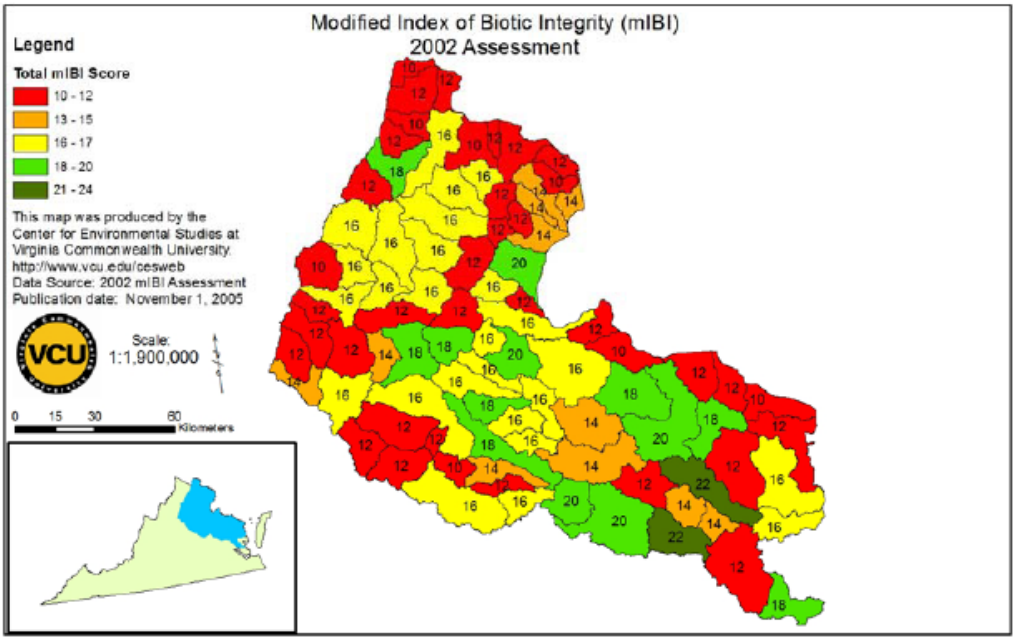
INSTAR assessment of specific stream reaches is based on percent comparability to appropriate, regional reference stream models (i.e., *virtual* streams) described in the above text. Stream reaches with strong (>75%) reference comparability scores are characterized by high ecological integrity and exceptional physicochemical conditions. In contrast, stream reaches with poor (<25%) reference comparability scores exhibit degraded ecological integrity and compromised physicochemical conditions. By early 2006, the ecological health of approximately 600 stream reaches—primarily in the Virginia Coastal Zone—will be evaluated using the novel INSTAR approach, which integrates over 50 ecological (biotic and abiotic) variables and metrics to assess stream condition. By combining results from INSTAR with complementary approaches to classifying terrestrial landscapes (e.g. Virginia Conservation Lands Needs Assessment; Division of Natural Heritage), the Commonwealth has, for the first time, tools to analyze complex relationships among elements of the Blue Infrastructure (e.g. water quality and stream-dependent living resources) and the Green Infrastructure (e.g. riparian buffers and land use) across broad geographic scales.

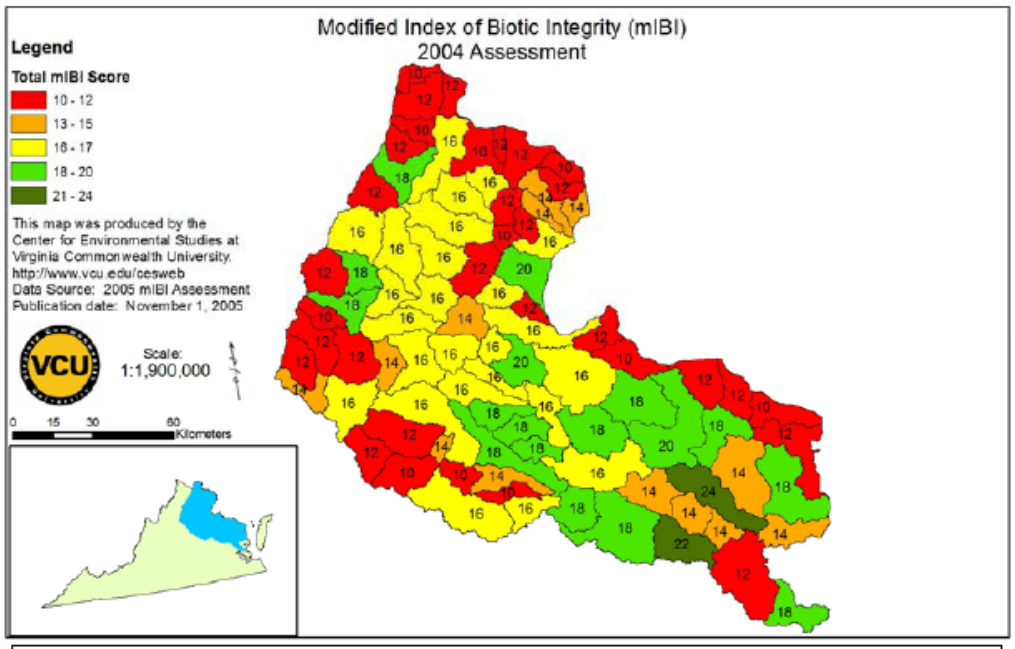


INSTAR-based classification of major Virginia river basins based on 2004 modified Index of Biotic Integrity (mIBI) scores for stream health assessment. The mIBI score ranges between 6 and 30; basins with scores < 14 (e.g. Shenandoah) are characterized by streams with generally low biotic integrity. In contrast, two basins (Dragon Run/Piankatank and Clinch) are dominated by streams with comparatively high biotic integrity.



INSTAR-based classification of 494 watersheds (HUCs) based on 2004 modified Index of Biotic Integrity (mIBI) scores for stream health assessment. The mIBI score ranges between 6 and 30; watersheds with scores > 17 are characterized by streams with generally high biotic integrity. The 2004 statewide assessment is based on approximately 150,000 records, including quantitative and qualitative data. Several small watersheds have no data for 2004 and are scored 'zero.'





The current (2004) mIBI stream assessment includes considerable new INSTAR data not available for the 2002 mIBI assessment. For a representative section of the Virginia Coastal Zone (above), the effect of these additional data on watershed-level stream assessments was substantial. Approximately one-third of the watersheds (HUCs) were classified differently in 2004 (lower map), compared to classification by the same mIBI protocol in 2002 (upper map), and there was a significant correlation between the number of additional records and the probability of a change in the mIBI stream health score in 2004. This finding suggests that accurate, statewide prioritization of streams and watersheds is influenced strongly by the quality and quantity of available data.

Utility of INSTAR

The *INSTAR* application (http://instar.vcu.edu) is an interactive, internet-based (ArcIMS) program that supports user-driven database queries, mapping functions, and quantitative biological and habitat assessments of stream reaches and watersheds, using algorithms and ecological models that compare selected sites to appropriate regional reference conditions. *INSTAR* is accessible from most computers via the internet and allows both technical and non-technical users to conduct sophisticated GIS and database tasks using an extensive stream database and multiple geospatial data layers. *INSTAR* is currently being used by a wide range of local, state, and federal agencies, academic researchers, and citizen-scientists. Funding for INSTAR has been provided by the Virginia Department of Conservation and Recreation, Virginia Coastal Zone Management Program (DEQ), EPA, and NOAA. For more information, visit http://instar.vcu.edu or contact Dr. Greg Garman, VCU Center for Environmental Studies at ggarman@mail2.vcu.edu or Dr. Len Smock, VCU Department of Biology, lsmock@mail1.vcu.edu.

Specific Accomplishments Under the Current Grant

1.) Field collection and data development

During the project period, extensive field sampling was conducted by VCU personnel throughout the Virginia coastal zone. Field effort targeted specific hydrologic units that were represented in the INSTAR database by less than eight (8) quantitative collections for fish and/or aquatic macroinvertebrate assemblages. These efforts complemented earlier INSTAR data development efforts within the coastal zone that were supported by VCZMP and DCR. The goal of the current grant was to support statistically valid stream health assessments (see above), based on living resources data, at 'reach-level' spatial scales. Sampling was conducted using standard field protocols at n>250 probabilistic sites within the targeted HUCs. Samples were processing in the field or were returned to VCU for further processing and analysis. Specific methods are described on page 4 of this report. Data generated represented fish and macroinvertebrate assemblages and instream habitat and were subjected to approved QA/QC procedures prior to posting on the INSTAR website. Approximately 8,000 new and quantitative records were produced by this extensive sampling effort. This objective was fully accomplished under the current grant.

2.) Migration to New Hydrologic (Watershed) Scale

After substantial discussion with VCZMP staff, it was decided that 'reach-level' resolution would be defined operationally on the basis of newly-developed, sixth-order watersheds (HUCs) that will be mandated for all regulatory and planning activities within Virginia by 2006. The new HUCs are approximately one-third as large as the previous fifth-order HUCs, which were in use when this study was developed. The new hydrologic boundaries were approved for use in Virginia late in 2005, after most of the fieldwork for this grant had been accomplished. However,

migration of the INSTAR database, application, and stream assessment algorithms to the new units will improve substantially the spatial resolution of stream health assessment in the region and will meet the original goal of the 'reach-level' language in the SOW. The migration objective was fully completed by VCU personnel under this grant. However, approximately 10% of the 'new' HUCs will not be sufficiently represented by the existing data and will require a limited data development effort in 2006-2007 to meet minimum data density standards for the coastal zone.

3.) Develop New Stream Models

Using the additional data, refined and updated 'virtual' stream models were developed and applied, based on the statistical methods described above (page 4), for the upper and lower Coastal Plain physiographic provinces and separately for first, second, and third order stream types. Models are used to classify specific stream reaches or HUCs based on percent comparability to appropriate, regional reference stream models (i.e., *virtual* streams) described in the above text. Stream reaches with strong (>75%) reference comparability scores are characterized by high ecological integrity and exceptional physicochemical conditions. In contrast, stream reaches with poor (<25%) reference comparability scores exhibit degraded ecological integrity and compromised physicochemical conditions. Specific model parameters are described at www.instar.vcu. This objective was fully accomplished under the current grant.